# FIDELITY MODULE

## INTRODUCTION

In this module, you will learn what the term fidelity means for the M&S community, explore some of the different dimensions and aspects of this concept, and examine how fidelity helps one make important tradeoff decisions within the field of M&S. You will also learn about some of the challenges involved in the fidelity of models and simulations.

To help you understand these fidelity issues, this module will utilize a simulation project-- The Virtual Environment for Submarine Ship Handling Training, or VESUB-- to illustrate core concepts (Naval Air Warfare Center, 1998). VESUB is a simulation used to train a US Navy submarine officer of the deck to safely bring a ship in and out of port. As you proceed through the module, you will not only examine fidelity concepts in the context of this simulation, but you will also examine how fidelity tradeoffs were made during VESUB's development.

Fidelity is a comparison of a model or simulation to the real world (DoD Directive 5000.59, 1994, P# 96). Since it is impossible to model or simulate everything, the fidelity comparison uses the real world as a baseline to help make tradeoff decisions about the characteristics of the model or simulation (The Project Manager Combined Arms Tactical Trainer, n.d.; Ivanetich, 1997.; Wolff, 1999, p. 8).

How much realism is good enough? How many and which features are necessary to meet the requirements of the simulation? Simulation fidelity provides a context to answer these questions.

## DEFINITION

In this topic, you will explore what fidelity means to the modeling and simulation community and learn to identify the different dimensions of fidelity. In the field of M&S, the term fidelity is defined as the degree of similarity between a simulated situation and the actual operational situation that is being simulated. It is impossible to model or simulate everything, so a choice must be made as to the level of fidelity for each of the major characteristics of a given simulation. Fidelity refers to the level of corresponding similarity between the model or simulation and reality (DoD Directive 5000.59, 1994, P# 96).

Fidelity can be conceptualized under two major dimensions: the *physical* characteristics of the situation – how it looks and feels; and the *functional* characteristics of the situation – what it does and how it works (Hays & Singer, 1989, p. 50).

**DRILL DOWN**, *Simulation Fidelity*

Hays, R. T., & Singer, M. J. (1989). *Simulation fidelity in training system design: bridging the gap between reality and training*. New York: Springer-Verlag, p. 50.

### Topic Summary:

To summarize, fidelity is the degree to which a model or simulation represents reality. Fidelity is made up of two different dimensions – physical fidelity and functional fidelity

## DIMENSIONS OF FIDELITY

In this topic you, will learn more about physical and functional fidelity, discover how these two dimensions affect one another, and examine the role that the purpose of a model or simulation plays in determining appropriate levels of fidelity. Physical fidelity is how a simulation looks; the physical characteristics of the simulation. Functional fidelity is how a simulation works or provides necessary information and action options to support the task. If the physical characteristics of the simulation are changed, its functional fidelity will also change. The two dimensions are interconnected.

**Activity:** Insert activity here.

The level of *physical* fidelity needed in a simulation should be determined by the *functional* requirements necessary to accomplish the goals of the simulation. To demonstrate, here is an example from VESUB. Let's see what happens if the level of visual detail –or physical fidelity—is reduced. As you can see, the objects are not very clear. With such low physical fidelity, the images cannot be used as cues for distance estimation. Thus, with this low level of physical fidelity, the simulation would not have enough functional fidelity—and the users could not perform the required tasks.

In the VESUB simulation, the Officer of the Deck is required to consult a chart of the harbor to locate relevant navigation aids. Therefore, the chart had to be represented on the screen with enough details, or physical fidelity to accomplish this task. A chart without enough detail to locate navigation aids would not provide enough functional fidelity to support the ship-handling task.

The characteristics of functional fidelity include the informational or stimulus options, and the action or response options provided by the simulation. These options must be determined with the end goal of the simulation in mind. For example, if it is a training simulation, the following questions should be addressed:

- What information does the user need to accomplish the task?

- How will the user obtain this information?
- What actions must the user take to accomplish the task,
- How does the user take these actions?
- What feedback information informs them that the task has been accomplished correctly?

Answers to questions like these help determine the functional requirements of the simulation. These *functional* requirements then drive decisions about how to design the *physical* characteristics of the simulation--as in the requirement to provide enough visual details to make distance estimations in the VESUB simulator.

**Topic Summary:**

This topic reviewed the two dimensions of fidelity; *physical*– how the model or simulation looks and feels, and *functional* – how it works. You also discovered that these two dimensions are interconnected. For example, when developing models and simulations, our decisions about the required levels of physical fidelity are driven by the characteristics of functional fidelity that we determined previously. Also, if the physical characteristics of the simulation are changed, then its functional fidelity will also change. And lastly, you explored how important it is to use the end-goal or purpose of the simulation when identifying its functional requirements.

## ASPECTS

Simulations can be very complex with many different subsystems. Fidelity tradeoff decisions must be made to determine the characteristics of each of these subsystems (The Project Manager Combined Arms Tactical Trainer, n.d.; Ivanetich, 1997; Wolff, 1999, p. 8). In this topic, you will learn about three example aspects of fidelity, and explore how feasibility and purpose play a major role in making fidelity tradeoff decisions.

Audio fidelity is an aspect familiar to most people. The term high fidelity, or hi-fi, is common within the context of stereo systems. It refers to a high quality representation of the original audio source. Audio fidelity is especially important in simulations that require the delivery of sound information – for example, voice communications, equipment sounds that may indicate problems, or other important sound cues.

In VESUB, one of the major training requirements was to teach communication skills to the members of the navigation team who were responsible for bringing the submarine into port. There were three alternatives during development of the simulation for allowing the trainee to receive verbal information from the simulation: a live instructor, computer-generated speech, or recorded speech. A *live instructor* was not possible because the instructor was too busy with other tasks in the training environment. The computer-generated speech was feasible, but it sounded like this.

That was somewhat difficult to understand, wasn't it? And it was pretty distracting. It didn't provide the appropriate level of audio fidelity when the simulation needed to "speak" to the trainee, nor did it provide sufficient audio fidelity to enable the users to efficiently accomplish their task. Since neither live nor computer-generated speech worked, VESUB developers explored the option of using recorded speech.

[Actual VESUB recorded speech is inserted here.]

As you can hear, the audio fidelity of this option was much more appropriate for this need than computer-generated speech. And it was also more feasible than having live instructors. Therefore, VESUB developers used digital sound files to play back the recorded live audio when triggered by the simulation. In this example, the right solution was found by focusing on the most feasible option that would meet the required end-use.

**Spotlight**: The requirements for end use should drive the level of fidelity.

Visual fidelity is a very important aspect of fidelity in simulations with visual displays. The fidelity of the visual display is usually determined by three characteristics: its resolution, number of pixels, and number of polygons (The Project Manager Combined Arms Tactical Trainer, n.d .)

Resolution is the degree of detail and precision used in the representation of real world aspects in a model or simulation (DoD Directive 5000.59, 1994, P#130). When used in the context of visual fidelity, resolution is a major component of visual quality. Here you see the same image from VESUB displayed on two separate screens, one at high resolution and the other at a lower resolution. While the higher resolution screen may be more appealing, it will also increase the cost of the model or simulation. Therefore, the best approach is to determine the *minimum* level of resolution required to meet the end-user's needs.

A pixel is a contraction of the phrase "picture element," hence the word pict-el, or pixel. A pixel refers to the smallest visual unit in an image on a computer display (DoD Directive 5000.59, 1994, P#123). More pixels means more visual information can be displayed which generally results in a sharper image (The Project Manager Combined Arms Tactical Trainer, n.d ). Again, using the same VESUB image from before, by increasing the number of pixels, the image becomes sharper when the number of pixels increases within a defined screen area. Reducing the number of pixels reduces the image quality lowering the visual fidelity.

A polygon is a flat plane figure with multiple sides (DoD Directive 5000.59, 1994, P#123). Polygons are the basic building blocks of virtual scenes. The more polygons a computer can display and manipulate per second, the more realistic the virtual scene will appear (The Project Manager Combined Arms Tactical Trainer, n.d ).

Looking at the VESUB image, the number of polygons can be seen by removing the textures, colors and shading applied to each polygon. Notice how rounded or curved surfaces require smaller polygons to create that surface. Reducing the number of polygons lowers the visual fidelity and increasing the number of polygons raises the visual fidelity of the simulation. However, this also increases the computing power necessary to display this image because each polygon has colors, texture maps, shading and light effects associated with it. The faster the computer processor and graphics display card operates, the more polygons can be drawn per second, and the more detailed the image displayed will appear.

**Spotlight:** Increasing the resolution, number of pixels, or number of polygons increases the cost of the simulation.

Another important consideration when determining the required level of visual fidelity is visual latency. In general terms, visual latency is the time between an input to the simulation and a change in the visual display (DoD Directive 5000.59, 1994, P#110). All other things being equal, the higher the visual fidelity, the longer the visual latency.

Referring to the VESUB example, in order for the trainee to determine if the ship was in the proper position in the channel, visually accurate navigation aids had to be displayed at great distances. To accomplish this, VESUB required a high-resolution head-mounted display rather than less expensive, lower resolution visual displays. It was found that trainees would become disoriented if the visual latency was less than 60 Hertz. This means that the visual fidelity could have had a direct negative impact on the success of the entire VESUB simulated experience if the correct choice, or tradeoff, had not been made. High-resolution head-mounted displays are expensive, but they provided a necessary level of realism to support the training objectives of the simulation. Cutting costs with a different type of display or slower computer processor would have had negative implications on the simulation's effectiveness.

This is another example of how the end-use must guide tradeoff decisions. If a less expensive option would result in a simulation that could not meet the ultimate end-use, then it is not a viable option—no matter how nice it would be to save money. In the end, this would actually waste money since the simulation would not fill the need for which it was developed.

Motion fidelity, also known as movement fidelity, is the motion of the simulation compared to the motion of the real operational system. Similar to latency in visual systems, there is also motion latency. Reducing the time between an action and its response in the motion system requires faster, more expensive computers. Using less accurate systems or ones where the latency delay is noticeable can have negative physical effects on the user such as disorientation or even nausea.

The types of motion or degrees-of-freedom also need to be determined. Some simulations only require up and down motion, or just 1 degree-of-freedom, while others may need motion in all directions or 6 degrees-of-freedom. There are three different translational degrees-of-freedom: heave, surge and sway . And there are three rotational degrees-of freedom : pitch, roll, and yaw. The more degrees-of-freedom needed, the more complex and expensive the motion system.

One of the tradeoffs that was made in the VESUB project was *not* to include a motion base. Including a motion base would have provided additional realism to the user, but the training requirements of VESUB were primarily visual, and since vision is the most dominant sense, it was determined that a motion system was not crucial to the training objectives. This helped to reduce the cost of the VESUB simulation while still providing high fidelity where appropriate and necessary.

Once again, it was the end-use that drove the final determination of which characteristics were essential to include and which ones were not required. Sometimes in using and developing simulations, people can develop expectations for high-levels of fidelity that may dramatically increase cost and that may not be necessary to accomplish the required objectives. To prevent this, it's best to work with the end-user to find the most feasible means for satisfying their requirements.

**Activity**: Insert activity here.

**Topic Summary:**

You learned about the three example aspects of fidelity – audio, visual and motion. When selecting or developing models and simulations, it is important to determine appropriate levels of these fidelity aspects by striving to meet the end-user's need in the most cost efficient, feasible manner.

A simple thing to remember is that the higher level of audio, visual or motion fidelity, the more costly it will be to produce. For visual fidelity, increasing the resolution, number of pixels and the number of polygons will increase visual fidelity and visual latency, but it will also raise the cost. For motion fidelity, reducing the motion latency, requires faster, more expensive computers. However, using less accurate systems can cause disorientation or even nausea. And for motion fidelity one must also determine what types of degrees-of-freedom are needed, including heave, surge, sway, as well as pitch, roll and yaw. The more degrees-of-freedom needed, the more complex and expensive the motion system.

The bottom line? Don't think of fidelity as a unitary concept. Rather, focus your efforts on finding what levels and characteristics of fidelity are required in each subsystem to meet the end needs of the user.

## CHALLENGES

In this topic, you will review some of the challenges that the Modeling and Simulation community faces when determining the appropriate level of fidelity required for a model or simulation—and hear from experts within the M&S field. As presented in the previous topic, one of the primary challenges when dealing with fidelity is making the determination of where to invest financial resources when developing a simulation. Deciding where to make allowances and where to make tradeoffs depend on which aspects of the simulation require which levels of physical and functional fidelity. All simulation projects have limits on available funds and time. In order to create effective simulations within those constraints, development teams have to make tradeoffs to best support the purpose of the simulation (The Project Manager Combined Arms Tactical Trainer, n.d).

A major challenge in modeling and simulation is to match the fidelity levels with the end-users' need. There are many technical capabilities to generate high fidelity – for sounds, images, or motion. However, high fidelity also brings with it high costs and additional time requirements. If the end-user requests high fidelity features that don't actually support the requirements, the simulation may be less effective.

Herb Grover has some thoughts on this issue…

> There is, at least in my experience, a growing trend towards creating a more accurate representation of weapons systems in simulations. But that is very labor intensive to do and expensive…Ultimately much of that depends on what the purpose of the simulation is and who the training audience is, what level of fidelity does that training audience require in order to execute their objective in that exercise?" (Herb Grover, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

As you work in the field of M&S, you will undoubtedly find that if you meet the user's requirements, the issue of fidelity will almost always determine itself.

End-users may have expectations of high fidelity for a simulation. These inflated expectations are sometimes due to what they see in the movies or in marketing information. Preparing the expectations of the end-user to match the levels of fidelity they will encounter in the simulations they will use is an important step in properly implementing M&S projects. Let's listen as Herb Grover shares his reflections about managing the user's expectations…

> When people are first introduced to Models and Simulations, many of them have little or no background apart from what they might have seen in the gaming industry. So, they come to the military and are expected either to use, or perhaps even to manage a Modeling and Simulation program without any exposure to what that simulation is designed to do. I would say that the first thing that needs to be brought to their attention is what the purpose of the simulation is, and the level of fidelity that they should expect. …We have to remind them that what is being displayed in this particular simulation is not for the visual delight of the operator. It is a visual graphic depiction of what is occurring in the battle space, but it is often elementary. It's not designed to be necessarily entertaining. It's a

> teaching tool. So, we help them understand that the icons that they see moving across the screen are not going to be what their kids might play with at home, but rather are just a tool to help them monitor the battle plan as its being executed. (Herb Grover, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

One of the important points from these comments by Herb Grover is that we can best prepare end-user's by *involving* them. As you will see in the Process Module, this involvement is necessary at every phase of the process, from defining the requirements to evaluating the final product.

Fidelity expectations are constantly changing as the field of M&S evolves. For example, in the 1980's a "high fidelity" visual system for a flight simulator cost millions of dollars and could only be built by specialty companies. Today, contemporary high fidelity visual systems of even greater quality than was available in the 1980's can be purchased for a home computer at very low costs. Because M&S continues to evolve, what is considered high fidelity today will change tomorrow. What remains a constant, however, is the need to determine the appropriate fidelity levels to meet the needs of the end-user. In this next video segment, Gary Fraas shares his perspective on the role of purpose in determining fidelity levels…

> "… in the … past there was always a high expectation of very realistic, high fidelity models. There has always been the question as to what do you really need the model to do, and how much realism do you actually need for the simulation, for the training application that you are intending the system to be developed for. So, that has always been controversial. We really have to understand what the war fighter really needs. In years past there was always the expectation that they needed the highest fidelity model that you could possibly get. Those are significant cost drivers in the development of a system. What we tried to do is really scale back and provide the level of fidelity that they actually need for the training application. (Gary Fraas, videotaped interview, ITSEC, November 2002, Orlando, FL: Integrity Arts & Technology, Inc.)

### Topic Summary:

To summarize, one of the biggest challenges that M&S faces regarding simulation fidelity is where to invest financial resources. Since high levels of fidelity are possible but require higher costs and time requirements, all simulations require tradeoffs. The best approach for managing this obstacle is to match the fidelity levels with the end-users' needs (The Project Manager Combined Arms Tactical Trainer, n.d ). Additionally, since the end-users' expectations about fidelity levels may be unrealistic, and may actually *change* during the project, it is important to prepare them for the levels of fidelity that are feasible and appropriate.

## FIDELITY MODULE SUMMARY

This topic reviews the major concepts presented in Fidelity module. Fidelity is the degree to which a model or simulation represents reality. It is made up of two different but interconnected dimensions. Simply stated, physical fidelity is how a simulation looks, while functional fidelity is how a simulation works. Decisions about which characteristics of functional fidelity to include while developing a model or simulation, will drive the required levels of physical fidelity. Additionally, if the physical characteristics of the simulation are changed, its functional fidelity will also change.

There are at least three aspects of fidelity to consider while building or selecting a model or simulation: audio, visual and motion. Since high levels of fidelity for any of these aspects increases the cost and time requirements, be careful to use end-user requirements as a guide when deciding on various tradeoffs. Also, since your end-users may have unrealistic expectations about fidelity, be certain to keep them involved so that they are prepared for the levels of fidelity that are feasible and appropriate.